A

02/06/98

REQUEST FORM FOR APPLICATION UNDER 37 CFR 1.53(b)

DOCKET NUMBER: **3395-002A**
Prior Application:
Art Unit: **1102**
Examiner: **B. Bell**

Assistant Commissioner for Patents
Washington, DC 20231

Sir:

This is a Request for filing a [x] Continuation, [ ] Divisional, [ ] Continuation-in-Part application under 37 CFR 1.53(b) of pending prior application Serial No. 08/518,646, filed on August 24, 1995, entitled **MODULAR CERAMIC OXYGEN GENERATOR** , by the following named inventor(s): Victor P. Crome

1. [X] I hereby state that the enclosed copy of this prior application is a true copy of the above-identified prior application.

2. Oath or Declaration
   a. [] Newly executed (original or copy)
   b. [x] Copy from a prior application (37 CFR 1.63(d))
      i. [ ] Deletion of inventor(s)
      Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).

3. [x] Incorporation By Reference (useable if Box 2b is checked)
   The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 2b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.

4. [x] Preliminary Amendment is enclosed.

5. [X] An Information Disclosure Statement and PTO1449 Form are submitted herewith.

6. [x] Cancel claims 1-3.

7. The filing fee is calculated on the basis of the claims existing in the prior application as amended at 4 and 6 above:

	NO. OF CLAIMS		EXTRA CLAIMS	RATE	FEE
Total Claims	11	MINUS 20	0	x $22 =	$0.00
Independent Claims	3	MINUS 3	0	x $82 =	0.00
				Basic Application Fee	790.00
				If multiple dependent claims are presented, add $270.00	
				Total Application Fee	790.00
				Subtract 1/2 if small entity	
				TOTAL APPLICATION FEE DUE	$790.00
				CHECK ENCLOSED IN AMOUNT OF $790.00	790.00

7a. [ ] Enclosed is a Verified Statement to establish small entity status under 37 CFR 1.9 and 37 CFR 1.27.

7b. [ ] A verified Statement to establish small entity status under 37 CFR 1.9 and 37 CFR 1.27 was filed in prior application and such status is still proper and desired.

8. [X] The Commissioner is hereby authorized to charge fees under 37 CFR 1.16 and 1.17 which may be required, including any extension of time fees to maintain the pendency of the parent application Serial No. 08/518,646 or credit any overpayment to Deposit Account No. 07-1337.

9. [X] Amend the specification by inserting before the first line the sentence:

--This application is a continuation of Application Serial No. 08/518,646 filed August 24, 1995.--

10. [ ] Priority of Application Serial No. filed on , in is claimed under 35 USC 119. The certified priority document(s) were filed in Serial No. on .

11. [x] The prior application is assigned of record to Litton Systems, Incorporated

12. [x] The power of attorney in the prior application is to:

Harold Gillmann and Gerald L. Lett

13. [x] Also enclosed:

4 pages of drawings (as filed in original application);
Two months Extension of Time (for parent application)

14. [x] A petition, fee and response has been filed to extend the term in the pending prior application until February 14, 1998.

Address all future communications to: (May only be completed by applicant, or attorney or agent of record)

Kenneth M. Berner
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Respectfully submitted,

LOWE HAUPTMAN GOPSTEIN & BERNER, LLP

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February 6, 1998

Docket No.: 3395-002A

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of	
Victor CROME	Serial No. To be assigned
Continuation Application of Serial No. 08/518,646	Group Art Unit:
Filed:	Examiner:

For: MODULAR CERAMIC OXYGEN GENERATOR

PRELIMINARY AMENDMENT

Honorable Commissioner of
Patents and Trademarks
Washington, D. C. 20231

Sir:

Before examining this continuation application on the merits (parent application Serial No. 08/518,646), kindly enter the following amendments and remarks.

IN THE CLAIMS:

Please cancel claims 1-3 in their entirety, without prejudice or disclaimer to their underlying subject matter.

4. (Amended) An [A ceramic oxygen generator comprising: an] ionically conductive ceramic element [electrolyte] comprising [including]:

a plurality of tubes each having interior and exterior surfaces, and each having a closed end and an open end [ends];

a tube support member [having first and second surfaces through which extend openings for] receiving [said] open ends of said plurality of tubes[, said open ends of said tubes appearing at said second surface];

a first electrically conductive coating covering said exterior surfaces of said plurality of tubes [and said first surface of said tube support member forming a first electrode connectable to a source of electrical potential of a first polarity];

a second electrically conductive coating covering said interior surfaces of said plurality of tubes [and said second surface of said tube support member forming a second electrode connectable to a source of electric potential of a second polarity,]; and

[means forming a manifold for collecting gasses appearing at said open ends of said tubes and said second surface of said tube support member.]

said first ceramic element having at least two columns and a first electrode covering an exterior surface of said first column and an interior surface of said second column of tubes and a second electrode covering an exterior surface of said second column of tubes and an interior surface of said first column of tubes;

said first electrode being connectable to a source of electrical potential at a first polarity and said second electrode being connectable to a source of electrical potential at a second polarity.

5. (Amended) The ceramic element [oxygen generator] described in claim 4 wherein said plurality of tubes are formed into rows and columns on said tube support member [with portions of said first and second surfaces interposed between the rows and columns and further comprising:

means forming an electrical surface from said first and second electrodes] wherein each tube is connected to said first electrode and said second electrode and first and second electrode portions of each of said tubes in a column are electrically connected in parallel and wherein each of the tubes forming a row are electrically connected in series.

6. (Amended) The ceramic element [oxygen generator] described in claim 5 wherein said first and second electrodes are formed by [means forming an electrical circuit comprises:]

cuts [formed] in said first and second electrically conductive coatings [electrodes] between said columns of tubes, said cuts extending longitudinally of and between the columns of tubes so that the portions of said first and second electrodes on opposite sides of each said cut are electrically separated, vias extended through said first and second surfaces adjacent each of said tubes and

electrical connections extending through said vias connecting a first electrode portion of each said tube in a row to a second

electrode portion of a tube in an adjacent column in the same row to form a series connection across each row of tubes.

7. Line 1, change "oxygen generator" to --element--.

Please add the following new claims:

--8. The ceramic element described in claim 4, wherein each the plurality of tubes is spaced from adjacent tubes.--

--9. An oxygen generator, comprising:

a first ceramic element having a tube support member and an array of tube members extending from said tube support member and formed into columns and rows;

a second ceramic element adjacent said first ceramic element; and

a seal between said first ceramic element and said second ceramic element;

said first ceramic element having at least two columns and a first electrode covering an exterior surface of said first column and an interior surface of said second column of tubes and a second electrode covering an exterior surface of said second column of tubes and an interior surface of said first column of tubes;

said first electrode being connectable to a source of electrical potential at a first polarity and said second electrode being connectable to a source of electrical potential at a second polarity.--

--10. The oxygen generator of claim 8, wherein said first ceramic element includes a first electrically conductive coating covering exterior surfaces of each of said plurality of tube members; and

wherein said first ceramic element includes a second electrically conductive coating covering interior surfaces of said plurality of tube members.--

--11. The oxygen generator of claim 8, wherein said first ceramic element is integrally formed.--

--12. An electrochemical element, comprising:

a ceramic element having a tube support member and an array of tube members extending from said tube support member;

wherein said tube support member and said array of tube members are formed from ceramic.--

--13. The electrochemical element of claim 12, wherein said ceramic element is an electrolyte.--

--14. The electrochemical element of claim 12, wherein said ceramic element is integrally formed.

REMARKS

Reconsideration and allowance of this application in view of the foregoing amendments and the following remarks is respectfully requested. A Petition for an extension of time is being submitted concurrently herewith for parent application Serial No. 08/518,646 to maintain copendency.

Claims 4-7 remain pending in the application. New claims 8-14 have been added. Claims 1-3 have been cancelled.

In the Office Action dated April 14, 1997 in parent application Serial No. 08/518,646 claims 1 and 3-7 stand rejected under 35 U.S.C. §103 as being unpatentable over Singh et al. (5,306,574) in combination with Riley (4,943,494) and Makiel (4,640,875). Existing claims 4-7 and new claims 8-12 are believed patentable over this combination of references for the reasons discussed below.

Independent claim 4 is directed to an ionically conductive ceramic element. Independent claim 9 is directed to an oxygen generator. Claim 4 includes a first ceramic element which includes a plurality of tubes and a tube support member. Both the plurality of tubes and the tube support member are made from the ionically conductive ceramic material. Claim 9 recites a "first ceramic

element having a tube support member and an array of tube members extending from said tube support member and formed into columns and rows." Both independent claims 4 and 9 (and new independent claim 12) require the support member and tubes to be ceramic. Further, in claim 4 the electrodes are formed of electrically conductive coatings.

By contrast, Singh discloses an electrochemical cell 12 having an interior electrode 14, an exterior electrode 16 and solid oxide electrolyte 15, between the electrodes. Electrodes 14, 16 and electrolyte 15 are supported by a porous concentric support 13. Each porous concentric support 13 is inserted into a porous barrier 30. Singh notes in column 2, lines 42-44, that "[e]lectrolyte 15 must be a solid material through which oxygen ions can diffuse or permeate." Thus, the porous barrier 30 is not an electrolyte.

Thus, Singh does not disclose a ceramic element having a ceramic support member or ceramic tubes as required by claim 4 nor does it disclose a first ceramic element recited in claim 9. Further, Singh has different electrical connections between electrodes than those recited in claim 4. For example, in Singh the electrical connections between adjacent electrodes are made through direct contact interconnection on the outer periphery of each of the cells. By contrast, the electrodes in claim 4 are formed from electrically conductive coatings. Although the series parallel arrangement required in the present invention is the same

as that disclosed in Singh, the manner in which the electrical connections are made is different.

Riley does not overcome the deficiencies noted above with respect to Singh. Riley merely discloses the prior art configurations disclosed in Singh and Makiel but manifolds together a plurality of SOFC modules 50 within a plurality of ceramic blocks 92-99 arranged in a stack configuration. Thus, with respect to the present invention recited in claims 4 and 9, Riley is irrelevant.

Further, Makiel does not overcome the deficiencies noted above with respect to Singh. Makiel discloses the same electrical connections as those disclosed in Singh and Riley. Makiel discloses in column 6, lines 1-8 that "[t]he oxidant conduits 20 are <u>preferably loosely supported</u> at one end in the sheet 34 as best shown in Fig. 4. The sheet 34 is preferably stainless steel with bores 60 that fit loosely about the conduits 20 to allow free thermal expansion. The conduits 20 are preferably comprised of alumina, and the sheet 34 is covered with an insulation such as low density alumina. A <u>small leakage</u> of oxidant, as indicated by arrow 63, is acceptable." This leakage, although acceptable in a fuel cell, is unacceptable for use in the oxygen generators recited in the invention of claim 8. It should be noted that porous partition 32 allows flow between chambers 14 and 16 (see col. 5, lines 12-19). The porous partition 32 is a porous ceramic such as fibrous alumina felt (furnace insulation). Thus, Makiel does not disclose

a ceramic element required in claims 4, 9 and 12 on the electrical interconnections required in claim 4.

Additionally, the nickel felt interconnections required by Riley would oxidize (rendering them useless) under oxygen generator operating conditions. These nickel felt interconnections are acceptable for the solid oxide fuel application for which they are intended as disclosed in Makiel.

Thus, it is believed that all of the presented claims are clearly patentable over the applied combination of references. Accordingly, the obviousness rejection of claims 4-7 should be withdrawn. The remaining dependent claims are patentable for the reasons discussed above with respect to claims 4 and 9 as well as on their own merits.

All objections and rejections having been addressed, it is respectfully submitted that the present application is in condition for allowance, and a Notice to that effect if earnestly solicited.

To the extent necessary, a petition for an extension of time under 37 C.F.R. 1.136 is hereby made. Please charge any shortage in fees due in connection with the filing of this paper, including

Serial No. to be assigned

extension of time fees, to Deposit Account 07-1337 and please credit any excess fees to such deposit account.

Respectfully submitted,

LOWE HAUPTMAN GOPSTEIN & BERNER, LLP

Kenneth M. Berner
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Date: February 6, 1998
Facsimile: 703-518-5499

MODULAR CERAMIC OXYGEN GENERATOR

Background of the Invention:

This invention relates to devices for separating oxygen from a more complex gas containing oxygen to deliver the separated oxygen for use More particularly, the invention relates to solid state electrochemical devices for separating oxygen from a more complex gas

It has been demonstrated that oxygen can be removed from more complex gasses, such as air, by an electrochemical process of ionizing the oxygen molecules transporting the oxygen ions through a solid electrolyte and reforming the oxygen molecules on the opposite electrolyte surface An electric potential is applied to a suitable catalyzing electrode coating applied to the surface of the electrolyte which is porous to oxygen molecules and which acts to dissociate oxygen molecules into oxygen ions at its interface with the electrolyte The oxygen ions are transported through the electrolyte to the opposite surface, which is also coated with a catalyzing electrode and electrically charged with the opposite electric potential which removes the excess electrons from the oxygen ions, and the oxygen molecules are reformed

The material forming the ion conductor, as is known, is a ceramic, and a wide variety of ceramics have been found useful for this purpose For example, as discussed in U.S. patent number 5,385,874 doped metal oxide ceramics have been found to provide high oxygen ion conductivity. The metal oxide may comprise from about 75% to about 90% of the overall composition, and typical oxides used to form the basis of the compositions may include zirconia, ceria, bismuth oxide, thoria, hafnia and similar materials known in the ceramics art. These are but examples, and the specific selection of material is not a part of the invention described herein.

As discussed, the generation of oxygen from electroded ceramic electrolytes or ion conductors is well known. These principles have been used in a wide variety of structural forms, i.e., the shape

of the ceramic electrolyte and the arrangement of electrodes on or within the electrolyte have taken a variety forms Each of these forms, however, has been found to have significant disadvantages in terms of the amount of surface area available for oxygen generation per unit volume and weight, the electrical connections have been difficult to manage, the collection devices for the oxygen output are difficult to manufacture and integrate with the electrolyte and the sources of gas from which oxygen is to be separated often are restricted

For example, in some of the devices of this type, the ceramic electrolyte is constructed as a large flat plate, and this has significant disadvantages It is limited in its ability to withstand high output delivery pressures Consequently, the plate must be either thicker, have stiffening ribs or have short spans between the sealed edges all of which add significantly to cost and manufacturing complexity

U.S patent number 5,302,258 describes a device where a plurality of tubes each having electrodes on the interior and exterior surfaces thereof, are used The tube design is an improvement in terms of its ability to withstand higher pressures However, considerable labor cost are are involved for sealing each tube to a manifold and to make the necessary electrical connections to each of the tubes

U S patent number 5,205,990 describes a honeycomb configuration which provides a less expensive way to produce the necessary surface area for the process and is structurally adequate to withstand the higher delivery pressures desirable The ceramic electrolyte in this configuration has a series of channels, a portion of which are electroded with a first polarity, and the others of which are electroded with a second polarity; these channels are said to form the honeycomb appearance. This arrangement has significant disadvantages in the labor required to seal the ends of numerous oxygen collecting channels and the wiring needed to connect those same channels. The alternating rows of oxygen and air channels provide only half the effective surface area as might be available from the amount of ceramic electrolyte used, and the electrical connections throughout this honeycomb structure are intricate and expensive to manufacture.

It is therefore an object of this invention to provide a ceramic oxygen generator having an electrolyte configuration which provides for an increased active surface area per unit volume and weight of ceramic material.

Another object of this invention is to provide a ceramic oxygen generator wherein the electrical connections to the individual anode and cathode surfaces are simplified and less costly to make

A further object of this invention is to provide a ceramic oxygen generator wherein the manifold structure for receiving the separated oxygen is an integral part of the manufactured generator structure and is less costly to make

Still another object of this invention is to provide a ceramic oxygen generator which is of a modular configuration and thereby provides a simple "building block" approach to meet differing requirements for amounts of oxygen to be generated

An additional object of the invention is to provide a ceramic oxygen generator meeting the foregoing objectives which is capable of operating with oxygen containing entrance gasses of a wide variety of pressures.

Summary of the Invention

The foregoing and other objects are achieved in a modular ceramic oxygen generating system constructed according to the invention wherein an ionically conductive ceramic electrolyte is molded to have a plurality of tubes extending from a support member forming a module. The tubes are closed at the ends thereof outermost from the foregoing surface while open ends of the tube form openings in the support member for the tubes All surfaces of the electrolyte including the inner and outer surfaces of the tubes and the top and bottom of the support member are coated with a porous ionizing electrode material in a continuous fashion. A second coating of a different material may be applied to the same surfaces, if desired, to act as a low resistance current carrier and distributor. The tube-

like members are formed into rows and columns on the tube support member. The aforementioned coatings of material are formed into electrical circuits which are created such that the columns of said tubes are connected in parallel while the rows thereof are connected in series. The tube support member includes a lower surface which is adapted to be joined with a like surface of another element to form an oxygen generator module assembly A number of module assemblies can have their output ports connected together to form a system of greater capacity.

Brief Description of the Drawings

The principles of the invention will be more readily understood by reference to the description of a preferred embodiment given below along with the drawings which are briefly described as follows

Figure 1 is a top perspective view of one of the molded, modular elements used to form module assembly of two molded elements creating the ceramic oxygen generator module assembly according to the invention

Figure 2 is a top perspective view of the two of the figure 1 molded elements formed into the aforementioned module assembly

Figure 3 is a bottom plan view of the figure 1 embodiment

Figure 4 is a partial cross sectional view taken along the line 4-4 of the figure 1 embodiment.

Detailed Description of the Drawings

In each of the figures of the drawings like elements are referred to with like reference numerals.

The ceramic oxygen generating assembly according to the invention is generally comprised of pairs of molded "building block" or modular elements such as the one depicted in figure 1. The

modular element 10 can be, for example, injection molded of an ionically conductive ceramic electrolyte and in the configuration shown provides a large surface area per unit volume, and it includes an integral manifold structure (to be described) for collecting oxygen. As is shown in figure 2 the symmetry of the modular design of element 10 allows a second element 10' to be inverted and sealed to the first element to form the assembly.

Referring again to figure 1, as stated, the element 10 is, for example, formed by an injection molding process from an ionically conductive ceramic electrolyte By this molding process element 10 is formed into a series of tubes 12 extending from a generally planar tube support member 14. In this embodiment the tubes are formed into 28 columns of 8 tubes each, or stated another way, 8 rows of 28 tubes each The outer end of each tube 12 is closed at 15. The upper surface 16 and outer surfaces 13 of the tubes 12 along with the closed ends 15 thereof, are then coated with a catalyzing and electrically conductive material. (See figure 4). Likewise, the lower surface 18 (figure 3) and interiors 17 of each of the tubes 12 are coated with a similar electrically conductive material. These coatings form the two electrode surfaces separated by the ceramic electrolyte. As best shown in figure 3, a series of vias 20 are provided, which are simply holes extending through the ceramic electrolyte, and these holes are plated through (and filled or plugged) during the electroding process. After the electroding process, the electrode material on portions of the upper and lower surfaces 16 and 18 may be burned away to form the desired electrical connections (to be described) through certain vias

As stated, the elements 10 and 10' forming the figure 2 assembly are identical and symmetrical so that they may be placed together in the manner shown in figure 2 to form complete assembly. A flange member 22 extends outwardly from the lower surface 18 of tube support member 14 around the perimeter thereof so that when the elements 10 and 10' are placed together as in figure 2 the flange members 22 and 22' are joined to form a manifold 24 in the interior thereof between the lower surfaces 18 of the two elements 10 and 10'. As best shown in figure 3, an exit port 26 is provided in tube support member 14 to communicate with the interior of manifold 24. Outlet ports could also exit along the longer edges of the elements 10 and 10' to allow side- by-side rather than end-to-end

connection of a plurality of assemblies

Figure 4 is a partial cross sectional view taken along the line 4-4 in figure 1. Thus, figure 4 is a cross sectional view of four tubes from a row of 28 in the described embodiment. As can be seen, the tubes 12 and tube support member 14 are of the ceramic electrolyte material. The outer surfaces 21 of tubes 12 and the upper surface 16 of tube support member 14 are continuously coated with an ionizing and electrically conductive material to form an electrode for the time being continuously covering these surfaces Likewise, the interior surfaces 23 of tubes 12 are coated with an electrically conductive material, and this coating 34 continues to cover the lower surface 18 of tube support member 14. As mentioned, in this electroding process, the vias 20 extending through tube support member 14 will be filled with the electrically conductive material The entire surface area is coated such as by a dipping process

In order to form these coatings into electrical circuits capable of creating oxygen generation devices of the above described type it is necessary to selectively burn away certain of the electrode material to produce the desired electrical connections To this end, a series of cuts in the electrode material 24 on the lower surface 18 of tube support member 14 are made as shown at 30 a-c. These cuts may be made with a suitable laser These cuts extend longitudinally of the columns the full dimension of tube support member 14 between each of the columns of tubes 12. Likewise, cuts 32 a-d are made in the electrode surface 21 formed on the upper surface 16 of tube support member 14. Again, these cuts 32 extend longitudinally the full dimension of tube support member 14 along each column of tubes 12 It will be noted, for example, that cut 32a is made on the side of via 20a nearer tube 12a while cut 30a is made on the side of via 20a nearer tube 12b. Thus, a series connection is made between electrode surface 21 of tube 12b and that portion of electrode surface 24 on tube 12a. The same relationships will then occur between the first and second electrode surfaces of the next succeeding tubes in the row, and this same relationship will follow in each of the rows. By allowing the electrode material to remain in the vias 20 the best possible low resistance connection between the tubes is formed.

The cuts 30 and 32 made longitudinally of columns of tubes, such as the cuts 30a and 32a between columns formed by tubes 12a 12b, and the like cuts between the other columns of tubes, in effect, form the tubes in a column into a parallel electrical circuit.

The result of this arrangement, using the figure 1 embodiment as an example, is that in the combination of 28 columns of 8 tubes each (8 rows) the electrodes (first and second electrodes) of each tube in each column of 8 tubes are in parallel electrically. Each of the 28 columns are in series electrically It should be noted that this arrangement is only exemplary and the sizes of the tubes and the arrangement of the rows and columns of tubes can be varied allowing the design to be an optimized arrangement of the series and or parallel electrical connections to each tube for best voltage and current distribution In the illustrated example, if it is assumed that the figure 1 module receives power from a 24 volt supply, the voltage applied across each tube would be less than one volt because each column of tubes acts in effect, as one of 28 series resistors. The voltage required to effect the ionization and transport oxygen across such a device is affected by several parameters including operating temperature, differential oxygen partial pressure across the generator, ionic conductivity of the electrolyte, electrical resistance of the electrolyte, electrode interface, spreading resistance of the electrode and resistance of the electrical connections to the generator. In general, however, this voltage is less than one volt and can be a small fraction of a volt in optimized designs. The number of tubes (or columns of tubes) is dependent on the power supply voltage and the desired voltage to be applied to each tube It is to be understood that each column of 8 tubes (and associated vias) in this example could be further subdivided such that 8 separate series of 28 tubes each are formed However, nonuniformity of electrode characteristics could cause localized overheating and subsequent burnout of one tube resulting in the loss of the series of 28 tubes. Arranging the tubes into columns as shown with multiple vias provides redundancy and normalization of the current flow.

In operation, the air or other gas from which oxygen is to be extracted flows across the tubes 12 and by reason of the principles of ionic conductivity discussed hereinabove, a gas having a higher pressure of oxygen is formed in the interiors of tubes 12 and is collected in manifold 24. This supply of oxygen is communicated via port 26 to the component having the oxygen requirement.

It is to be understood that while circular or cylindrical tubes having exterior and interior surfaces are shown in the described embodiment other configurations for the "tubes" could be used and the term "tube" is used herein only for purposes of convenience of reference.

An alternative arrangement to each column of hollow tubes is a hollow "cantilever shelf" configuration which would provide approximately the same effective surface area. These flat hollow sections with one end molded closed would be manifolded together as the tubes are to provide a common output port Internal stiffening ribs could be added between the opposing flat walls to increase the ability to withstand internal pressure as required.

The principles of this invention are described hereinabove by describing a preferred embodiment constructed according to those principles It will be understood that the described embodiment can be modified or changed in a number of ways without departing from the spirit and scope of the invention as defined by the appended claims

CLAIMS

1. An ionically conductive ceramic electrolyte element for an oxygen generator comprising:

a plurality of tubes having interior and exterior surfaces and having open and closed ends.

a tube support member having first and second surfaces through which extend openings for receiving said open ends of said plurality of tubes, said open ends of said tubes appearing at said second surface and

means for forming a manifold for collection of gasses from said open ends of said tubes.

2 The ceramic electrolyte element for an oxygen generator described in claim 1 wherein said plurality of tubes and said tube support member are formed as an integral structure by molding process

3 The ceramic electrolyte module for an oxygen generator described in claim 1 wherein said means for forming a manifold includes a joining member extending from said tube support member adapted to be joined to a like member on a second said ceramic electrolyte element.

4 A ceramic oxygen generator comprising:

an ionically conductive ceramic electrolyte including:

> a plurality of tubes having interior and exterior surfaces and having closed and open ends;
>
> a tube support member having first and second surfaces through which extend openings for receiving said open ends of said plurality of tubes, said open ends of said tubes appearing at said second surface;

a first electrically conductive coating covering said exterior surfaces of said plurality of tubes and said first surface of said tube support member forming a first electrode connectable to a source of electrical potential of a first polarity;

a second electrically conductive coating covering said interior surfaces of said plurality of tubes and said second surface of said tube support member forming a second electrode connectable to a source of electric potential of a second polarity, and

means forming a manifold for collecting gasses appearing at said open ends of said tubes and said second surface of said tube support member

5. The ceramic oxygen generator described in claim 4 wherein said plurality of tubes are formed into rows and columns on said tube support member with portions of said first and second surfaces interposed between the rows and columns and further comprising:

means forming an electrical surface from said first and second electrodes wherein first and second electrode portions of each of said tubes in a column are electrically connected in parallel and wherein each of the tubes forming a row are electrically connected in series.

6. The ceramic oxygen generator described in claim 5 wherein said means forming an electrical circuit comprises:

cuts formed in said first and second electrodes between said columns of tubes, said cuts extending longitudinally of and between the columns of tubes so that the portions of said first and second electrodes on opposite sides of each said cut are electrically separated,
vias extended through said first and second surfaces adjacent each of said tubes and

electrical connections extending through said vias connecting a first electrode portion of each

said tube in a row to a second electrode portion of a tube in an adjacent column in the same row to form a series connection across each row of tubes.

7. The ceramic oxygen generator described in claim 6 wherein said electrical connections are constituted by the material forming said first and second electrodes coating the surfaces of said ceramic electrolyte extending through said vias

ABSTRACT OF THE DISCLOSURE

A ceramic oxygen generator is described which is capable of modular construction to permit the oxygen generation capacity to be expanded. An ionically conducted ceramic electrolyte is formed into a series of rows and columns of tubes on a tube support member and like electrolyte bodies can be connected together to form a manifold therebetween for oxygen produced in the interiors of the tubes. An electrical connection between tubes is formed such that the anodes and cathodes of tubes in a column are connected in parallel while the tubes in the row are, respectively, connected anode to cathode to form a series connection.

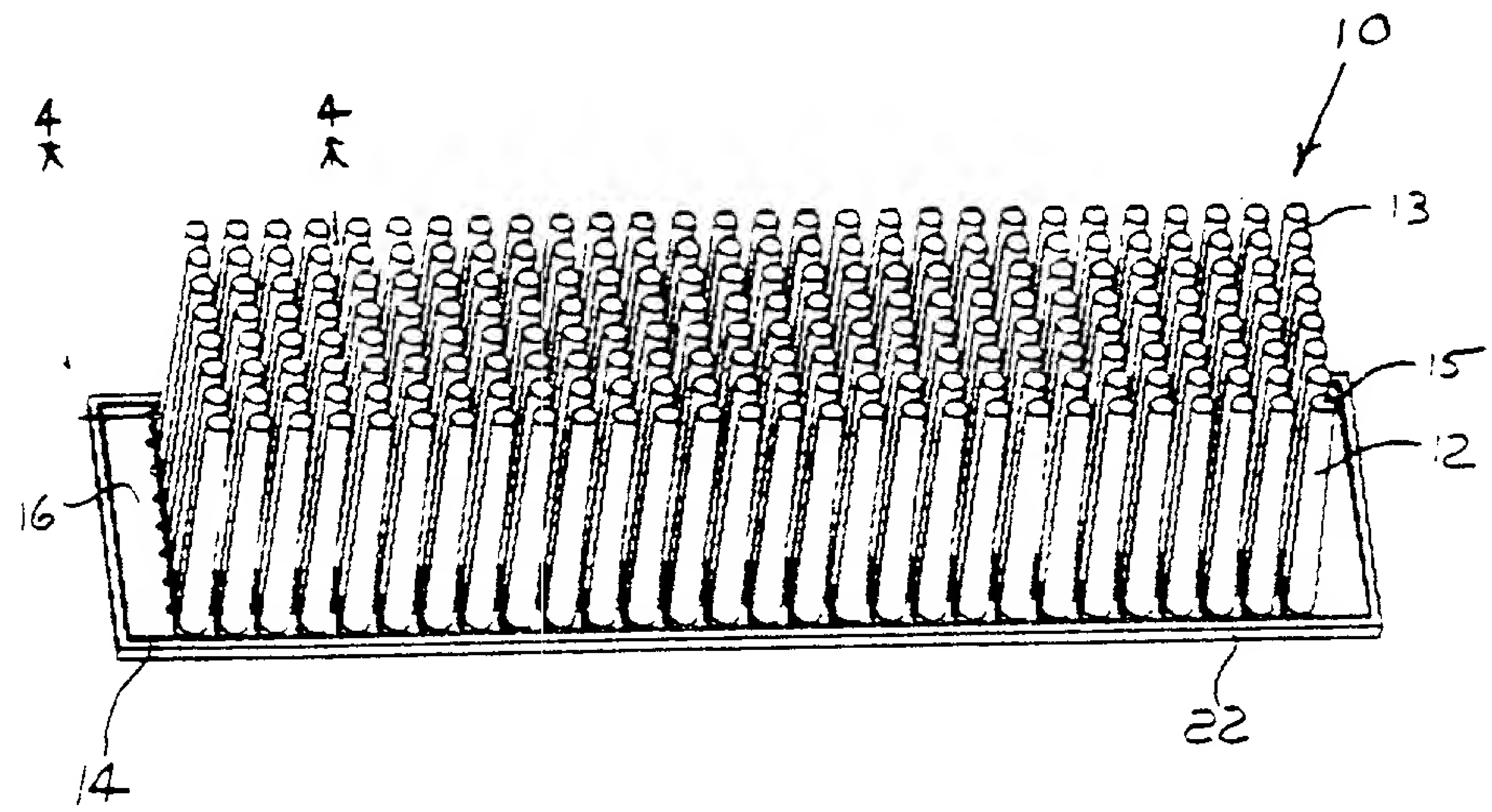


FIG 1

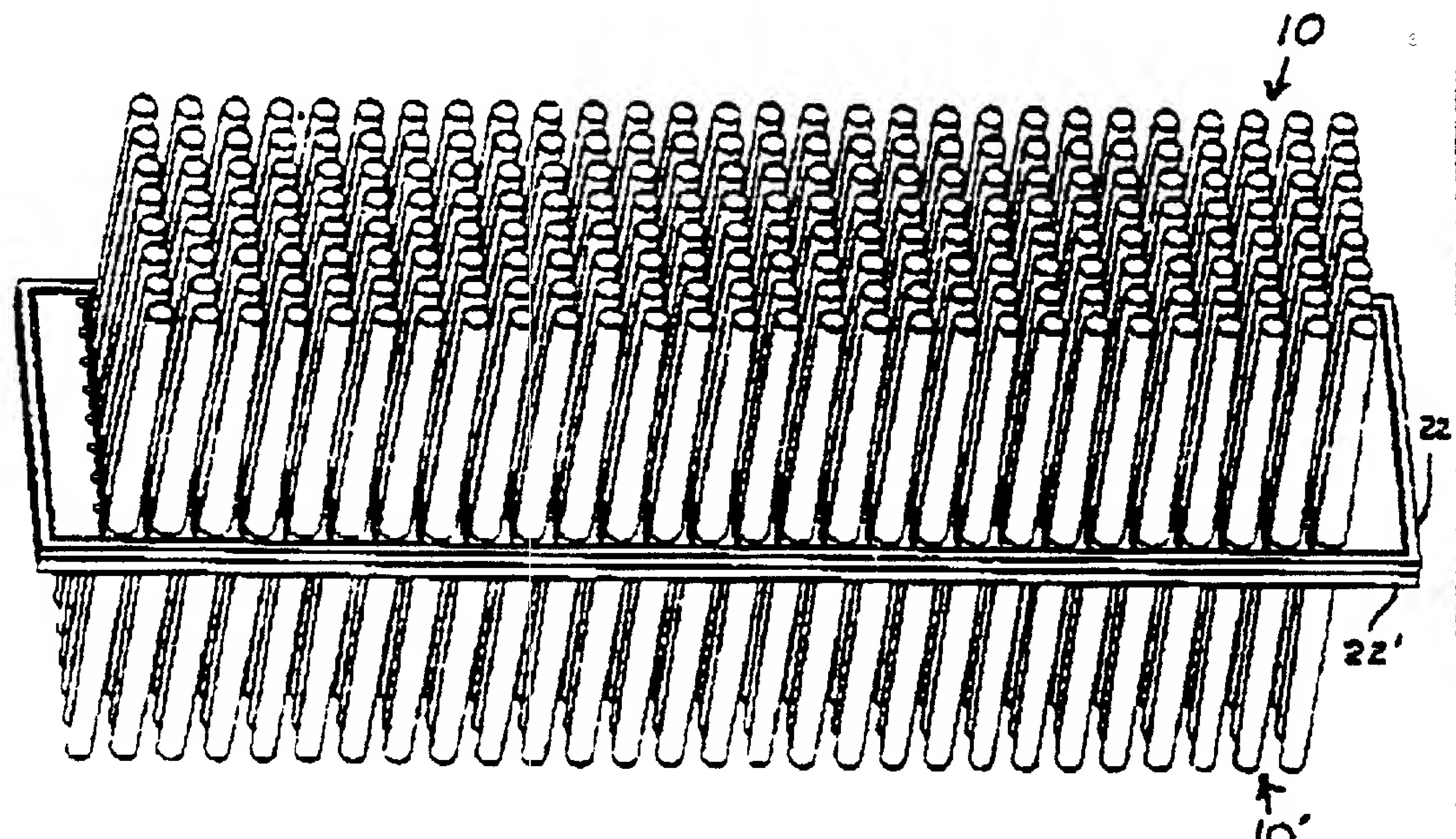


FIG. 2

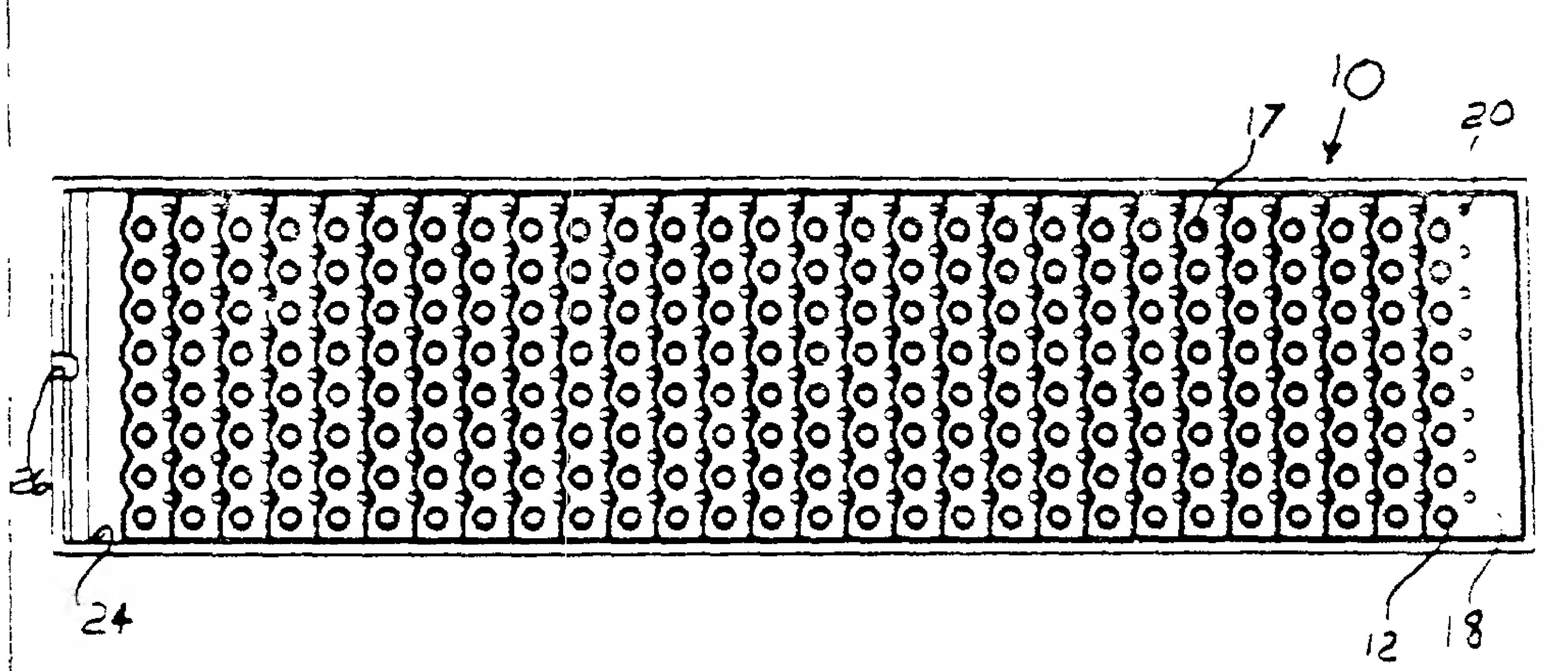
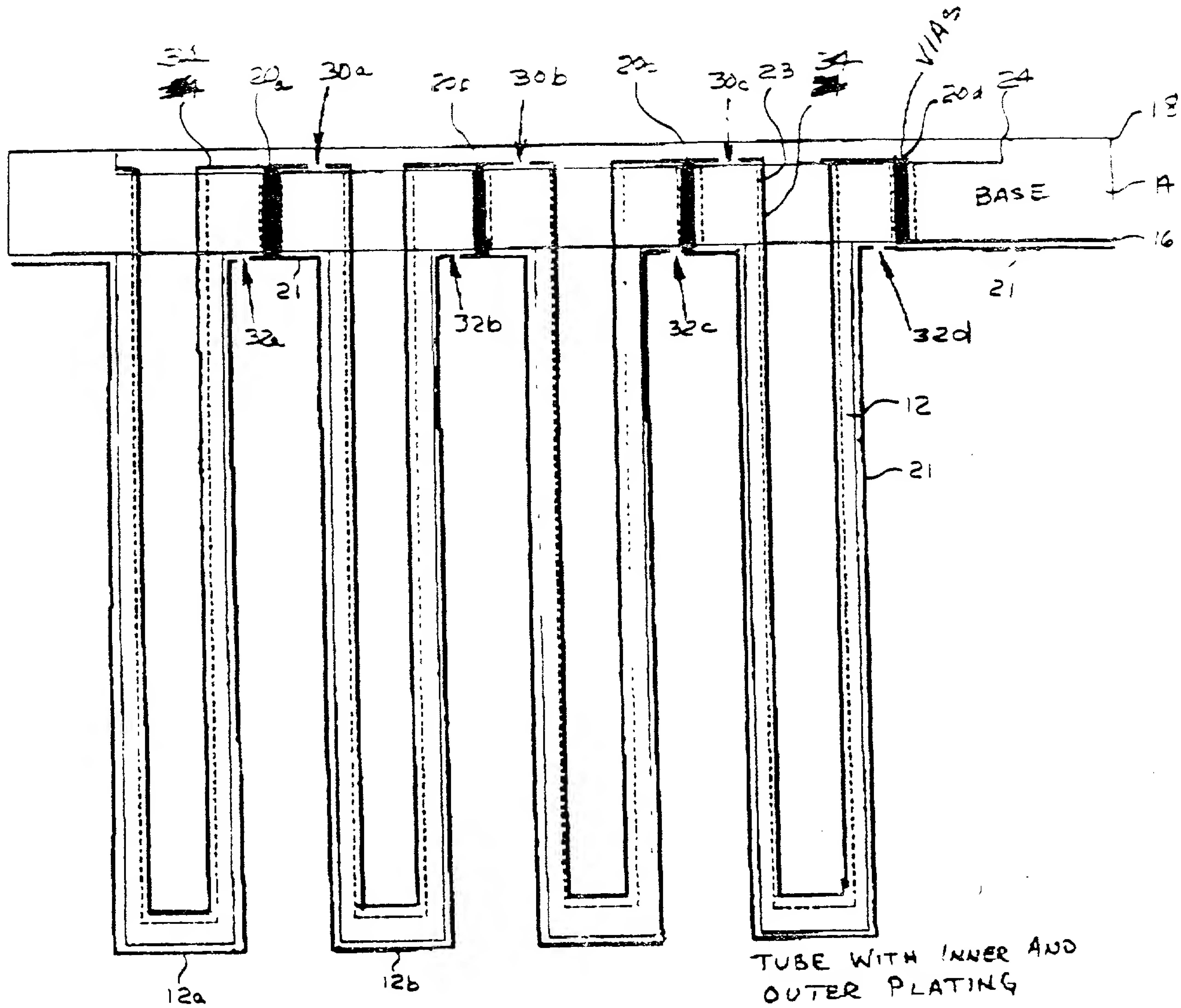


FIG 3

LASER CUTS AT ARROWS CREATE SERIES CONNECTIONS.



ONLY 4 ROWS OF TUBES SHOWN FOR SIMPLICITY

FIG. 4

X-SECT.WG2

DECLARATION AND POWER OF ATTORNEY

I, Victor P Crome, the below named inventor, hereby declare that:

My residence, Post Office address and citizenship are as stated below adjacent to my name.

I believe I am the original and first inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **"Modular Ceramic Oxygen Generator"**.

I hereby state that I have reviewed and understand the content of the above identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, code of Federal Regulations, Paragraph 1.56(a).

I hereby appoint the following attorneys to prosecute this application and transact all business in the Patent and Trademark Office connected therewith: Harold Gillmann, Registration Number 25,336 and Gerald L. Lett, Registration Number 24,509. Please address all further correspondence concerning this application to Gerald L. Lett; 5115 Calvert Road; College Park, Maryland 20740; telephone number 301-454-9965.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the Unites States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Victor P. Crome   8/15/95

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